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Semiannual Status Report

PERFORMANCE MEASUREMENT OF INTELLECTUAL FUNCTIONING

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FOR THE PERIOD: 1 October 1965 to 31 March 1966

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SUMMARY

This is the first semiannual status report to be submitted under Grant No. SC/NGR-18-002-008, "Performance Measurement of Intellectual Functioning." It covers work completed during the six-month period, 1 October 1965 through 31 March 1966.

Work during this period has followed closely the lines presented in the proposal on which the grant is based (submitted on 9 June 1965). Progress to date has been at a faster rate than initially anticipated. A prototype of the apparatus required for presentation and scoring of the operator's performance of the code-transformation (COTRAN) task has been designed, constructed and tested. A first experiment, designed to measure the effects of two task parameters (the number of memory aids available to the operator, and the number of code transformations required per problem solution) on performance, has been completed. A second experiment is complete through the data-collection phase, and data analysis has begun; this experiment was designed as a correlational study of the performances obtained from different operators on the COTRAN task and on selected tests of intellectual ability, problem-solving behavior, and personality characteristics.

No insolvable difficulties have been encountered during the period, and none is expected during the remainder of the period of work. Efforts are scheduled to be lightened on this work during the early part of the summer (when personnel are to be away for data collection on another project), and increased during the late part of the summer (when personnel return) and early fall (when student-subjects become available).

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INTRODUCTION

This is the first semiannual status report to be submitted under Grant No. SC/NGR-18-002-008 between the University of Louisville and the National Aeronautics and Space Administration. This research on the "Performance Measurement of Intellectual Functioning" is being conducted under the direction of Dr. Earl A. Alluisi, Professor of Psychology, and is monitored by the Human Performance Branch, Biotechnology Division, Life Sciences, NASA Ames Research Center, Moffett Field, California. This report covers work completed during the period 1 October 1965 through 31 March 1966.

The purpose of the present research is to develop a task for the performance measurement of intellectual functioning. The task is to meet certain criteria of validity, sensitivity, engineering feasibility, reliability, flexibility, work-load variability, trainability, and control-data availability as defined elsewhere (see Alluisi, 1964; Alluisi & Fulkerson, 1964). The specific goals set in the proposal for the three-year program of research are as follows:

- o Design, construct, and test equipment for the task to be used.
- o Establish, through empirical research, the parameters of the task (e.g., effects on performance of problem-difficulty levels and rates of presentation of problems) both when the task is used alone and when it is used as part of a multiple-task performance (MTP) battery.
- o Correlate performance on the task with performance on selected tests of intellectual ability, personality characteristics, etc.
- o Measure reliability of the task in both statistical and engineering (equipment) terms.
- o Prepare "standardized" instructions and procedures for employment of the task.

In reporting on the status of the research in this and in future reports, a general outline will be used in order to provide continuity without sacrifice of brevity. The outline will have obvious relations to the specific goals of the research. Status and progress will be reported in the appropriate sections and subsections of the outline.

1. DEVELOPMENT OF THE COTRAN TASK

1.1 Background in Performance Measurement.--No additional work has been required in this area; see "Introduction" and "Background in Performance Measurement," pp. 2-4 of the Proposal for Research.

1.2 Background in Measuring "Intellectual Functioning".--No additional work has been required in this area; see "Background in Measuring 'Intellectual Functioning,'" pp. 4-5 of the Proposal for Research. (A relatively complete review of this background material has been prepared and will be submitted for possible publication prior to, or with, the final report.)

1.3 The COTRAN Task.--A "code-transformation" (COTRAN) task has been designed to provide performance measures of intellectual functioning. The task is a modification of the "code-lock solving" task that is used as a group-performance task in a current multiple-task performance (MTP) battery (see Alluisi & Fulkerson, 1964, p. 14; Alluisi, Hall, & Chiles, 1962, pp. 5-6). In its modified form, it is an individual rather than a group-performance task. Although it was described in the Proposal for Research (pp. 6-7), a description is given below to permit a clearer understanding of the present report.

The working elements of the COTRAN task are displayed to the operator on a panel and keyboard. These elements consist of five response keys (arranged to correspond with the natural placement of the finger tips of the right hand) and three indicator lights (red, amber, and green). The task may be described as consisting of three phases (four phases were listed in the Proposal for Research, but the last two of these have been combined into a single phase in the present description). These three phases of the task are described in the following paragraphs.

In phase I, the operator is required to discover the proper sequential order of depressing the five response keys--one for each finger of the right hand. Illumination of the red light is the signal that a problem is present and unsolved. The amber light is illuminated when the operator depresses any of his response keys, thereby indicating that his response has been registered. When the response key is released, the amber light is extinguished; the red light remains illuminated unless the key that was depressed is the "correct" first response. If it is, then the red light is extinguished at the same time as the amber light, and it will remain extinguished until an "incorrect," or out-of-sequence, response is made. When this occurs, the red light will be re-illuminated, and the programming apparatus will be reset automatically to the beginning of the sequence. In order to recommence the search for a solution, the correct first response key has then to be depressed first, the correct second response key has to be depressed next, etc. When all five response keys have been depressed in the correct order, the green light will be illuminated as a signal that the problem presented in phase I has been solved. Following a between-phase pause of about 30 seconds, the green light will go off, the red light will come on, and the operator is presented with phase II of the COTRAN task.

Phase II is identical to phase I, except, of course, that it involves a different sequence. Also, it follows phase I and, thereby, may be more difficult depending on the memory load imposed by requiring that the operator recall both solutions during the last phase. Before describing this last phase, which is the "problem-solving" or "intellectual-functioning" phase of the task, it may be appropriate to call attention to some of the properties of phases I and II. Since all 120 of the possible sequences are used, in random orderings on successive presentations of phase I, the operator has no way of knowing what the correct sequence will be when a problem is presented. Rather than having him search for this sequence in an unsystematic trial-and-error fashion (with different operators' using, perhaps, different methods), all operators are instructed to use consistently a systematic search procedure. This also permits expectancies to be established as to the number of errors (i.e., re-illuminations of the red light) ideally obtained with each sequence; operators can thereby be scored in terms of their deviations from the ideal solutions. These comments hold also for phase II, except that there are some constraints on the selection of the "correct" sequence as will be seen below.

During phase III, the operator is required to deduce, from the sequences (or solutions) of phases I and II, the transformation that must have been applied to the sequence of phase I in order for it to have generated the sequence of phase II. That is to say, he has to determine how the phase-I sequence would have had to be changed in order for it to have produced the phase-II sequence. Then, he must apply the deduced transformation to the phase-II sequence in order to predict a phase-III sequence. That is to say, the operator has to predict a third sequence, and test his prediction by applying it to a presentation similar to those made in phases I and II.

It is in phase III that the operator is faced with the task of solving a problem in the usual sense of the "problem-solving" paradigm. In fact, were the sequences of phases I and II presented to the operator directly, and were the results of his phase-III deductions to be reported vocally, in writing, or in some other symbolic way, the task could be described as a typical problem-solving task. It is the requirement that the operator apply his solution during phase III, using the same displays and controls that were used in phases I and II, that distinguishes the COTRAN task as providing performance measures of problem-solving activity. Thus, it is proposed as a performance task that provides direct measurements of intellectual functioning.

Three blue indicator lights have been added to the display during the period covered by this report. The lights appear below the principal display (the red, amber, and green lights) and are used to inform the operator of the problem phase. Thus, when the left-most blue light is illuminated, it is meant to inform the operator that he is working in phase I. The center and right-most blue lights are used similarly for phases II and III.

2. DESIGN AND CONSTRUCTION OF COTRAN APPARATUS

2.1 Prototype Equipment.--Prototype equipment for presentation, programming and scoring the COTRAN task was designed, constructed, and tested during the past six months. The apparatus is electro-mechanically activated. The subject's or operator's part of the apparatus consists of three basic components: a response unit, an information or display unit, and a memory unit. The experimenter's or controller's apparatus consists of two components: a programming unit and a scoring unit.

The subject's response unit consists of five telegraph keys arranged to correspond with the natural placement of the fingers of the right hand. Exact placement of the keys was based on data collected from ten male and ten female subjects. An enclosure was placed over the keys so that only the 1-inch diameter response buttons protruded.

The subject's information unit, on which the information necessary for solution of the problem was presented, consisted of six jeweled indicator lights, three blue and one each red, amber, and green. The lights were mounted on a small, tilted-panel, cabinet.

The subject's memory unit, when used, permitted the subject to record a discovered sequence, or in some conditions both sequences from phases I and II. Thus, the memory unit consisted of either one or two memory aids. Each memory aid consisted of five, 5-position 1-inch rotary switches arranged horizontally. Each switch could be set to one of five numbers (1 through 5). Each switch corresponded to a keyboard (or finger) position.

The experimenter's programming unit consists of three banks of five 5-position rotary switches, one bank for each of the three phases of the problem. Of course, these switches are appropriately connected to a stepping switch and a series of relays that serve to define the problem and score the subject's responses. The scoring unit, in conjunction with the programming unit, permits the experimenter to monitor the subject's performance at all times. The subject's errors and response times (to the nearest 0.1 second) are recorded on electro-mechanical counters for each phase.

The apparatus has been used in collecting the data of two studies; it appears to be highly reliable and easily maintained.

2.2 Standardized Equipment.--It is anticipated that a final design will be developed near or at the end of the three-year program of research. This design will make use of solid-state components, if feasible, and will call for appropriate packaging. No progress has been made in this area during the past six months.

3. SINGLE-TASK STUDIES OF COTRAN PERFORMANCE

3.1 Studies of the Parameters of the COTRAN Task.--One of the specific goals of the research program is to establish the relevant parameters of the COTRAN task through empirical investigations. Two parameters that can be expected to affect operator performance are (1) the number of memory aids available to the operator, and (2) the complexity of the transformation employed in the problems presented to the operator.

Pilot experimentation was conducted with the COTRAN task in order to obtain estimates of the difficulty of the task, the solution rates to be expected, and the feasibility of using all possible values of the two parameters of the task identified above. The results of this pilot study indicated that when no memory aid was provided, the task was too difficult to be used as a performance-assessment instrument; some operators required as long as 20 minutes to solve a single problem under such conditions. Also, the data indicated that even when three memory aids were provided (one for each phase), the operators chose to use only two (for the first two phases) and entered the phase-III solution directly onto the keyboard. Thus, on the basis of this pilot experimentation, it appears that the meaningful range of the number-of-memory-aids parameter is from one to two aids.

Similarly, it was decided that the meaningful range of the complexity-of-transformation parameter is from three-element transformations to five-element transformations. Although two-element transformations are possible, they constitute a trite problem and, in addition, they form a population of only ten cases for any given problem--a population that is too small for adequate representation in experimental use.

Following the pilot experimentation, and the decisions cited above, an experiment was conducted to measure the extent to which the two parameters would affect operator performance on the COTRAN task. Two memory-aid conditions (one versus two aids available) were combined factorially with three transformation-complexity conditions (three-, four-, or five-element transformations) to form six experimental conditions. Fifteen subjects were assigned at random to each of these six conditions. The subjects were 90 undergraduate students (48 females and 42 males) enrolled in introductory psychology at the University of Louisville. They ranged in age from 16 to 29 years, with a median age of 19. Each subject was tested for a total of 1000 seconds excluding the 30-second intervals between problems and between phases I and II (and, of course, excluding the instruction and training periods). Nine direct, and six derived measures of performance were recorded for each subject; these data were then analyzed in two ways. First, the measures were intercorrelated and factor analyzed. Secondly, representative measures were selected on the basis of the factor analysis, and these were then used to assess the effects of the parameters of the task on COTRAN performance.

The results of the factor analysis indicated, in brief, that three factors are involved in the measures of COTRAN performance employed. After rotation, these factors appear to be meaningfully identified as:

- o Over-all COTRAN Accuracy
- o Over-all COTRAN Speed
- o Problem-solving Accuracy (or, Phase-III COTRAN Accuracy).

Accordingly, seven measures were selected for further analysis. These seven measures consisted of two identifying measures from each of the three factors, and one measure that was approximately equally loaded on each factor and which, therefore, provides a "composite" score. An analysis of variance of the data provided by each of these seven measures was computed on the basis of the 2-by-3 factorial design of the experiment. The results of these analyses indicated that the one-memory-aid condition produced lesser performance than the two-memory-aid condition with six of the seven measures (the two conditions were not significantly different in the case of the seventh measure). Neither the transformation dimension nor the interaction of transformations with memory aids was found to be significant with any of the seven measures.

A complete report of this study will be prepared and submitted for possible publication prior to, or with, the final report.

3.2 <u>Studies of the Reliabilities of the COTRAN Measures</u>.--Reliability coefficients could not be computed meaningfully from the data of the study reported above. The first of the correlational studies (described in 3.3, below) has been designed, however, to permit such computations. Estimates of reliabilities will be available in the near future, as the data of the study are analyzed.

3.3 <u>Correlational Studies of COTRAN Performance</u>.--Since the COTRAN task has been designed to provide performance measures of intellectual functioning, it should be possible to establish some degree of construct validity. If the task is to measure validly differences in an individual's performance under different conditions (e.g., alert versus fatigued or sleep deprived), then it should reflect also the different abilities of different individuals working under a single set of controlled conditions. Likewise, the measures of COTRAN performance should correlate with measures of general intellectual abilities, to the extent that the two are correlated and are validly measured with the tests employed. In addition, it might be expected that the COTRAN measures might also be correlated with specific tests of intellectual characteristics that have been previously isolated and hypothesized to be related to problem-solving abilities. Finally, it is possible that the COTRAN measures are sensitive to personality variables, and the recognition of the sensitivity would be relevant to any full understanding of the nature of man's performance on the task.

In line with this reasoning, a second experiment was designed and data were collected during the past six-month period. The data are currently being analyzed, so no report of results can yet be made. The principal goals of the study were to correlate and factor analyze the results obtained from the COTRAN performances of different operators and the performances of these same individuals on a selected battery of paper-and-pencil tests. The paper-and-pencil tests were selected from among three general classes of instruments: (1) tests of general intellectual abilities, (2) tests based on certain factor-analytic studies of intellectual abilities, and (3) tests of certain personality characteristics.

As indicated earlier, a second goal of the study was to obtain estimates of the test-retest (actually, split-half) reliabilities of the seven measures of COTRAN performance selected previously (see 3.1, above). A third goal was to re-examine the possible effects of the transformation-complexity parameter on performance, and to assess the rates of improvement on the task with practice.

The study was conducted in two sessions for each subject: a COTRAN-performance session, and a group session in which the paper-and-pencil test battery was administered. The subjects for both sessions were 84 undergraduate students (50 males and 34 females) from various psychology classes at the University of Louisville. The subjects ranged in age from 17 to 30 years, with a median age of 19. Each subject was paid ten dollars ($10.00) for his 8-hour participation in the study.

During the COTRAN-performance session, a total of 18 problems was presented to each subject. The two-memory-aid condition was used throughout in order to maximize operator performance. The 18 problems presented to each operator consisted of six blocks of three problems each; the three problems in each block consisted of a three-, a four-, and a five-element transformation complexity.

During the paper-and-pencil testing session, each subject was administered a total of ten tests; these provided 32 scores per subject. The tests included two tests of general intellectual ability (5 measures), six tests based on a factor-analytic study of intellectual abilities (6 measures), and two tests of personality characteristics (21 measures).

As indicated earlier, this study has been completed through the data-collection phase, and data analysis is currently underway. A complete report of this study will be prepared and submitted for possible publication prior to, or with, the final report.

4. MULTIPLE-TASK STUDIES OF COTRAN PERFORMANCE.--Although work in this area has been planned as part of the three-year program of research, none was contemplated for the first-year effort. When work is started here, it is expected to follow the general outline of the single-task studies of COTRAN performance (see 3, above).

LIAISON ACTIVITIES

Dr. Donald R. Brown, Associate Professor of Psychology at Purdue University, visited the laboratory on 2 December 1965. Dr. William J. White, Staff Scientist, Douglas Aircraft Company, Santa Monica, California, visited on 9 December 1965, and Dr. Donald Meyer, Professor of Psychology at the Ohio State University visited on 17 February 1966. Major Jimmy S. Hatfield, MSC, visited on 8 November 1965.

Dr. Earl A. Alluisi (Principal Investigator) attended an invitational conference on performance assessment 29-30 March 1966 at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. He is scheduled to attend the 1966 meetings of the Southern Society for Philosophy and Psychology 7-9 April 1966 in New Orleans, La., and he is schedule to visit the NASA Ames Research Center 26-27 April 1966 in order to report verbally on the progress and status of this research.

DIFFICULTIES ENCOUNTERED

No major difficulties were encountered during the past six-month period, and, indeed, the research is currently ahead of schedule; data collection is now complete for the first-year portion of the research, but data analysis and the preparation of suitable reports have not been completed.

ANTICIPATED WORK

The remainder of the period of this grant will be devoted principally to data analysis and preparation of reports. Should all go well, however, time should be available during the last month of the period to begin collecting data of studies planned for the second year of work.

PERSONNEL

The personnel working on this grant during the past six months were E. A. Alluisi (Principal Investigator), G. D. Coates, Vesta Gettys, Ann V. Harvey, B. B. Morgan, Jr., and K. Rothrock. In addition, subjects were paid as indicated for participation in certain experiments.

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